

Chapter 8

Groundwater Development and Basin-wide Water Balance

Karl Taboga, James Stafford and Paul
Taucher

Several factors to consider when planning a groundwater development project include:

- Is the resource economically accessible utilizing current drilling, well construction, and water delivery technology?
- Is the water quality sufficient to meet the requirements of its intended use in either an untreated form or following cost effective treatment?
- Is the resource legally available? Legal and political considerations such as competing local water rights, aquifer and surface water depletion, and wildlife impacts constrain groundwater availability under the developing concept of sustainability.
- Can the aquifer provide sufficient quantities of water? Quantity pertains to the rate and duration of production that can be reasonably expected from the completed project wells.

Project engineers, scientists, water managers, operations personnel, and end users continuously evaluate these interrelated factors during a project because a substantial deficiency in any one area may render the entire project infeasible.

Groundwater development in the Bear River Basin is further constrained by the Amended Bear River Compact of 1978 (**Appendix D**) between the states of Utah, Wyoming, and Idaho. The compact limits and defines water appropriations from the Bear River for all three states. To effectively discuss groundwater development and use within a river basin, the term “withdrawal” and the concept of “consumptive use” must be defined and discussed. A groundwater withdrawal is simply the removal of a volume of water from a well or a spring at its source. The consumptive use of a water resource diminishes the amount of water available for other uses and effectively removes that water as a useable resource from the drainage basin. Consumptive processes include evaporation, transpiration, and injection into geologic units where depth and water quality preclude future withdrawal.

Relatively few uses are wholly consumptive. Most uses are partially consumptive in that some of the water is lost while the remainder is returned to the system until it flows out of the basin. For instance, a portion of the groundwater used for irrigation is lost to the consumptive processes of evapotranspiration while the remainder is delivered back to the basin’s water budget as return flows to surface waters or as recharge to groundwater. Other examples of consumptive uses include livestock watering, surface water evaporation and municipal, industrial and domestic. Some wastewater treatment depletions include discharge in sewage or septic systems where water is depleted through evaporation and transpiration. Industrial depletions can be in the form of evaporative cooling, wastewater storage and disposal in evaporation pits and water injection for enhanced oil and gas production. Throughout this study “use” has essentially the same meaning as “withdrawal,” and “depletion” has the same meaning as “consumptive use.” The preferred terms, in an attempt to minimize confusion, are “withdrawal” and “consumptive use.”

This chapter discusses groundwater development, total withdrawals, and depletions in the Bear River Basin using information compiled from multiple sources:

- Previous water plans for the Bear River Basin (WWC Engineering and others, 2007; Forsgren Associates 2001; Wyoming Water Development Office (WWDO), 2012);
- Numerous previous local and regional studies (**Appendix B, Chapter 7**);
- Groundwater permit data provided by the Wyoming State Engineer’s Office (SEO), the Idaho Department of Water Resources (IDWR), and the Utah Division of Water Rights (UDWR); and
- SEO 2012 Hydrographers’ Annual Report Water Division 4 (State Engineer’s Office, 2013) available at: <https://sites.google.com/a/wyo.gov/seo/interstate-streams/know-your-basin/bear-river-basin>.

8.1 Information from previous water plans

Total groundwater withdrawals, consumptive uses, and the methods used to quantify them in the Bear River Basin were described in the existing WWDC Statewide Framework Water Plan (WWC Engineering and others, 2007), which compiled and updated information from the 2001 Bear River Basin Water Plan (Forsgren and Associates, 2001), associated technical memoranda, and other on-line publications. Although the 2007 Statewide Water Plan summarized withdrawal and consumptive use information developed in the 2001 Bear River Basin Plan, there were small differences in the volumes reported between the two plans and the various technical memoranda. Direct measurements of irrigation uses were not provided in the WWDC Water Plans but were estimated based on related information. Estimates of consumptive uses associated with recreational and environmental uses of groundwater resources were not provided in the previous plans or technical memoranda.

8.2 Groundwater withdrawal and consumptive use estimations and basin-wide water balance

In the absence of direct measurements, groundwater withdrawals and consumptive uses must be estimated. While this may appear to be straightforward, in reality, it becomes quite complex because multiple estimations of the same parameter may be made using different methods and assumptions. Still, the methods used must provide reasonably conservative estimations of withdrawals and consumptive uses based on rational assumptions. Therefore, withdrawal and consumptive use values are presented, in the tables shown below, in multiple formats and as ranges of probable values. In some cases, very conservative estimations have been provided for comparison and are explained in the text that accompanies the table. See, for example, the range of annual irrigation withdrawal estimates from SEO data made in rows 2 - 3 of **Table 8-1a**.

The water resources of any river basin are not composed of static volumes of standing water. Unlike an area's mineral reserves, water is a dynamic

resource that enters a basin in the form of precipitation or as surface and groundwater flows from adjacent areas. Likewise, water exits a river basin as effluent surface and groundwater flows or as water vapor resulting from evaporation, and transpiration from plants (see definition, **Chapter 5**). It is important to understand the transient nature of water resources. For this reason, the Wyoming State Geological Survey (WSGS) generated a basin-wide water balance (**Tables 8-2a** and **8-2b**) to provide an understanding of the magnitude, origin and fate of water resources in the Bear River Basin.

8.2.1 Groundwater withdrawal and consumptive use estimations

Tables 8-1a through **8-1d** summarize and compare various groundwater withdrawal and consumptive use estimates from the SEO and previous WWDC water plans and technical memoranda (WWC Engineering and others, 2007; Forsgren and Associates, 2001; WWDO 2012) for principal SEO listed water right uses.

- Irrigation (**Table 8-1a**);
- Stock watering (**Table 8-1a**);
- Industrial uses (**Table 8-1b**);
- Community and non-community public supply (**Table 8-1c**);
- Rural domestic (**Table 8-1c**); and
- Other diverse uses (**Table 8-1d**) that involve miscellaneous, monitoring, test, multi-use wells, and are hereinafter, referred to as "minor uses."

Although the values developed for **Tables 8-1a** through **8-1e** and **Tables 8-2a** through **8-2d** are shown in some cases to a precision of 1 ac-ft., they are generally rounded to the nearest 100 ac-ft. in the following discussion. Percentages carried to one decimal place in the tables are rounded to the nearest whole value.

Estimates of total withdrawal and consumptive use volumes for the first five uses listed above are shown in **Tables 8-1a** through **8-1c** and are aggregated in **Table 8-1e**. Total annual groundwater withdrawal is 3,900 ac-ft and the corresponding value for annual consumptive use is 3,130 ac-ft

Table 8-1a. Groundwater withdrawal and consumptive use estimates for agricultural use wells (irrigation and stock watering) in the Wyoming portion of the Bear River Basin.

Use	Annual withdrawal (ac-ft/yr)	Annual consumptive-use (ac-ft/yr)	Percent consumptive use	Estimation method/ Data sources/ Notes
¹ SEO permitted irrigation wells	58,762	no estimate		SEO permitted yields for irrigation wells through 02/27/12. (See Table 8-6)
	11,605	no estimate		SEO permitted yields for likely existing irrigation wells through 02/27/12. (See Table 8-6)
¹ SEO permitted livestock wells	5,667	no estimate		Total permitted yield through 02/27/12. (See Table 8-6)
	4,214	no estimate		Permitted yield for likely existing stock wells through 02/27/12. (See Table 8-6)
^{2,3} Agricultural uses	2,400	1,900	80 - 100%	Irrigation and livestock use estimates are aggregated as agricultural uses. Mean annual crop consumptive use of groundwater for 1971 - 1998 in Bear River Basin is 80% of withdrawals. Stock use considered 100% consumptive.

Table 8-1b. Groundwater withdrawal and consumptive use estimates for industrial use wells in the Wyoming portion of the Bear River Basin.

Use	Annual withdrawal (ac-ft/yr)	Annual consumptive-use (ac-ft/yr)	Percent consumptive use	Estimation method / Notes
¹ Permitted industrial wells	2,847	no estimate		Total permitted yield through 02/27/12. (See Table 8-6)
	0	no estimate		Total permitted yield for likely existing wells through 02/27/12. (See Table 8-6)
² Industrial uses (primarily for gas processing)	5	5	100.0%	All industrial uses were assumed to be 100% consumptive
³ WOGCC Conventional Oil & Gas produced water (2005-2011)	466	222	47.6%	An estimated 47.6% of produced water was re-injected

(**Table 8-1e**). Water use categories, amounts, and estimation methods are discussed in more detail later in this chapter. Minor uses are not included in the totals shown in **Table 8-1e**, because they are not addressed in previous water plans and only SEO permitted withdrawal data (**Table 8-1d**) is available for them.

For other uses, potential volumes calculated from SEO allocated well yields are provided for comparison to estimates obtained from previous technical memoranda. The large differences between SEO allocated well yields and actual use estimates show that the volumes of groundwater actually used constitute a fraction of what has been allocated to permitted water right holders. For example, the total irrigation withdrawal calculated from SEO permitted yields for “likely existing wells” (11,605 ac-feet/yr in **Table 8-1a**) assumes continuous year-round operation of the permitted irrigation wells. Although, the value is clearly an overestimate, it does provide an instructive upper limit of groundwater withdrawals for irrigation. The estimates shown for agricultural withdrawals and consumptive uses of groundwater are aggregate values for both irrigation and stock watering (Forsgren and Associates, 2001; WWDO 2012). Irrigation consumptive uses were based on actual crop specific consumptive uses in the Bear River Basin collected over a 28-year period of record from 1971-1998. The methodology is

explained in **Appendix G** of the 2001 Bear River Basin Water Plan (Forsgren and Associates, 2001).

Table 8-1a: Estimates of total groundwater withdrawals and consumptive uses for irrigation and stock watering (combined as agricultural uses) obtained from various sources. Values from **Appendix G** (Forsgren and Associates, 2001) shown in **Table 8-1a** are used in **Table 8-1e**.

Table 8-1b: Estimates for various classes of industrial groundwater withdrawals and consumptive uses, shown in **Table 8-1b**, are compiled from SEO and WOGCC data and the previous 2011 Bear River Basin Water Plan (WWDO 2012). Note that the volumes of saline water produced from oil and gas operations are not generated as a groundwater resource, but only as a byproduct. These values therefore are not considered a reduction of beneficially useable groundwater resources but were provided for the reader’s information.

Table 8-1c: Estimates for municipal and domestic groundwater withdrawals and consumptive uses are shown in **Table 8-1c**. The ranges of consumptive uses, shown and aggregated with other uses in **Table 8-1e**, are compiled from previous water plans and technical memoranda (Forsgren and Associates, 2001; WWDO 2012).

Table 8-1c. Groundwater withdrawal and consumptive use estimates for municipal and domestic use wells in the Wyoming portion of the Bear River Basin.

Use	Annual withdrawal (ac-ft/yr)	Annual consumptive-use (ac-ft/yr)	Percent consumptive use	Estimation method / Notes
¹ Permitted municipal and domestic wells	17,550	no estimate		Total permitted yield through 02/27/12. (Table 8-6)
	8,530	no estimate		Permitted yield for likely existing wells through 02/27/12.(Table 8-6)
² Municipal / Community GW	801	692	86%	Groundwater withdrawals/use for Towns of Cokeville/Bear River
² Rural domestic	533	533	100%	Rural domestic use assumed to be 100% consumptive.
² TOTAL	1,334	1,225	91.8%	Combined municipal and rural domestic use

Table 8-1d. Permitted annual groundwater withdrawal rates for SEO monitor, multi-use and other wells in the Wyoming portion of the Bear River Basin.

Use	Annual withdrawal (ac-ft/yr)	Annual consumptive-use (ac-ft/yr)	Percent consumptive use	Estimation method / Notes
¹ Permitted municipal and domestic wells	17,550	no estimate		Total permitted yield through 02/27/12. (Table 8-6)
	8,530	no estimate		Permitted yield for likely existing wells through 02/27/12.(Table 8-6)
² Municipal / Community GW	801	692	86%	Groundwater withdrawals/use for Towns of Cokeville/Bear River
² Rural domestic	533	533	100%	Rural domestic use assumed to be 100% consumptive.
² TOTAL	1,334	1,225	91.8%	Combined municipal and rural domestic use
¹ Wyoming State Engineer's Office, 2012				
² Wyoming Water Development Office, 2012				

Table 8-1e. Total groundwater withdrawal and consumptive use estimates for all uses in the Bear River Basin.

Use	Annual withdrawal (ac-ft/yr)	Annual Consumptive-Use (ac-ft/yr)	Percent Consumptive Use	Estimation method / Notes
Total permitted yield Wyoming	¹ 128,631	no estimate		Total permitted yield through 02/27/12 (See Table 8-6)
	¹ 36,987	no estimate		Permitted yield for likely existing wells through 02/27/12 (See Table 8-6)
Total permitted yield Wyoming, Utah, Idaho	^{1,2,3} 295,163	no estimate		1,362 WSEO permits as of 02/27/12 1 IDWR permits as of 09/20/12 981 UDWR permits as of 09/20/12 (See Tables 8-6, 8-7, 8-8)
Estimated withdrawals and consumptive uses from Wyoming agricultural , municipal, domestic and industrial wells ^{4,5}	3,900	3,130	80.3%	Totals estimated in 2011 Bear River Basin Water Plan ⁴
	3,739	3,130	83.7%	Totals of estimates from Tables 8-1a, 8-1b and 8-1c
¹ Wyoming State Engineer's Office (2012)				
² Idaho Department of Water Resources (2012)				
³ Utah Division of Water Rights (2012)				
⁴ Forsgren and Associates 2001				
⁵ Wyoming Water Development Office, 2012				

Table 8-1d: Only SEO permitted withdrawal information was available for several minor uses - monitor, other, and multi-use wells.

Table 8-1e: Total groundwater withdrawal and consumptive use estimates are shown for principal SEO listed uses, all Utah Division of Water Rights (UDWR) and Idaho Department of Water Resources (IDWR) uses, aggregated values from **Tables 8-1a** through **8-1c**, and totals compiled from the 2011 Bear River Basin Water Plan and associated technical memoranda.

8.3 Basin-wide water balance

Tables 8-2a and **8-2b** contain mass balance water budget calculations for the Wyoming portion of the Bear River Basin. The primary objective of the water balance analysis is to provide a rational estimate of basin-wide evapotranspiration. In the process, withdrawal, consumptive use, and recharge data from this and other chapters in this report are conveniently compiled into one table. Armed with these estimates, first order approximations can be made of the proportions of precipitation destined for recharge, evapotranspiration, surface water outflows and consumptive uses from water resource development.

The analysis contained in **Table 8-2a** was adapted from the general water budget equation (Fetter, 2001):

Evapotranspiration = (precipitation + surface inflow + imported water + groundwater inflow) – (surface water outflow + groundwater outflow + reservoir evaporation + exported water + recharge) ± changes in surface water storage ± changes in groundwater storage.

- The assumptions used in this water balance are:
- No water is imported or exported into or from the Bear River Basin.
- Basin groundwater inflows equal basin groundwater outflows.
- Groundwater and surface water depletions are limited to consumptive uses from the municipal/domestic, livestock, and industrial sectors (SEO permitted uses).

- Annual changes in stored surface and groundwater equal zero.

8.3.1 Precipitation

Precipitation is the ultimate source of groundwater recharge. Average annual precipitation volume in the Bear River Basin for the 30-year period of record (POR) from 1981 to 2010 was calculated using GIS software and PRISM data (<http://prism.oregonstate.edu/> - Figure 3-3) at 1,398,195 ac-ft.

8.3.2 Surface water inflows and outflows

Average annual stream inflow and outflow data for the Wyoming portion of the basin were obtained from the USGS (<http://water.usgs.gov/>). Inflow data was retrieved from USGS stream gaging stations 10011500, 10012500, 10015700 and 10026500, all of which are sited near the Utah-Wyoming border on influent reaches of the Bear River and tributary streams.

Annual outflow data was recovered from USGS stream gaging stations 10020500, 10027000, 10039500, and 10041000. These stations are all sited on effluent reaches of the Bear River and tributary streams near Wyoming's borders with Utah and Idaho.

8.3.3 Evaporation from reservoirs

Evaporation data from the basin's reservoirs was obtained from Technical Memorandum XI of the 2011 Bear River Basin Water Plan (WWDO, 2012).

8.3.4 Depletions from municipal/ domestic, livestock, and industrial uses)

Surface water and groundwater depletions from municipal/domestic, livestock, and industrial uses were obtained from the 2011 Bear River Basin Water Plan (WWDO, 2012). Agricultural uses were not considered since 99.9 percent of irrigation water is lost to evapotranspiration and return flows that recharge underlying aquifers or discharge

Table 8-2a. Bear River Basin water resources mass balance.

WATER BALANCE PARAMETERS ^a		Average Annual Volume (ac-ft)
Precipitation (1981 - 2010 - Figure 3-3) ^b		1,398,195
Total surface water inflows ^c	+	340,337
Total surface water outflows ^c	-	503,592
Evaporation from reservoirs ^d :	-	5,361
Water exported (Surface water depletions from municipal/domestic, livestock, and industrial uses) ^d	-	2,676
Water exported (Groundwater depletions from municipal/domestic, livestock, and industrial uses) ^d	-	1,574
Total estimated Bear River Basin recharge (Table 6-3)	-	188,968
Basin-wide evapotranspiration	=	1,036,361

Comparative estimates

The Wyoming Climate Atlas^e indicates that, except for the highest elevations in Wyoming, the rate of evaporation exceeds the rate of precipitation by at least a factor of 4. The potential evaporation rate can greatly exceed the actual volume.

For comparison - total average annual precipitation: 1,398,195 x 4 =	5,592,780 acre-feet
Estimation evapotranspiration in the Bear River Basin using the USGS climate and land-cover data regression ^f .	
Total evapotranspiration	1,069,066 acre-feet

^aFetter, C. W., 2001

^bPRISM Climate Group, 2012

^cUSGS, 2012

^dWyoming Water Development Office, 2012

^eCurtis, 2004

^fSanford and Selnick, 2013

to surface water bodies (Colorado State University, 2013).

8.3.5 Total estimated Bear River Basin recharge

The recharge value shown is the “best total recharge” estimate for sedimentary aquifers calculated on **Tables 6-2** and **6-3** from the recharge fraction data of Hamerlinck and Arneson (1998) and PRISM (2013) precipitation data for the 1981 – 2010 POR.

8.3.6 Estimated basin-wide evapotranspiration

The water balance model adapted from Fetter (2001) and presented in **Table 8-2a** places basin-wide evapotranspiration at 1,036,361 acre –feet per year. For comparison, a value for potential evapotranspiration (5,592,780 acre-feet per year) was provided based on the premise that the rate of evapotranspiration exceeds the rate of precipitation by a factor of at least four (Curtis, 2004). Potential evapotranspiration is the amount of water that would evaporate and transpire if there is always a sufficient amount of water available in the soil

to meet demand (Sharp, 2007). In fact, actual evapotranspiration is limited to the amount of water available to the processes of evaporation and transpiration.

A second estimate of actual evapotranspiration (1,069,066 acre-feet per year) in the Bear River Basin is shown at the bottom of Table 8-2a. This estimate was obtained using a GIS based regression model developed by the USGS (Sanford and Selnick, 2013) from climate and land-cover data. The USGS ET estimate falls within 3.2% (32,705 acre-feet) of the estimate obtained using the water balance method.

8.4 Magnitude, origin and fate of water resources in the Bear River Basin

Table 8-2b shows that approximately 74 percent of precipitation is lost to evapotranspiration in the Bear River Basin, about 14 percent recharges the basin's aquifers and nearly 12 percent leaves as stream outflow. Evaporation from reservoirs constitutes less than 0.4 percent of total basin precipitation. Surface water and groundwater depletions from municipal/domestic, livestock, and industrial

uses comprise 0.2 percent and 0.1 percent of precipitation, respectively.

Table 8-2c summarizes various average groundwater withdrawal estimates from tables 8-1a through 8-1c as percentages of estimated recharge. Agricultural (irrigation and livestock) and aggregated municipal and domestic uses each constitute about 1 percent, industrial uses amount to less than 0.01 percent, and total groundwater withdrawals constitute about 2 percent of recharge. Estimated total annual consumptive uses (3,739 acre-feet - Table 8-1e) constitute about 2 percent of annual average recharge.

Estimated recharge (**Table 8-2c**) far exceeds average annual withdrawals of groundwater. Estimates of total average annual groundwater use could be substantially higher, and the estimates of recharge substantially lower, without significantly changing these simple comparative results.

Table 8-2d: It is also useful to evaluate future groundwater requirements relative to recharge. The 2001 Bear River Basin Water Plan (Forsgren and Associates, 2001) provides use factor-based estimates of total combined annual withdrawals and

Table 8-2b. Bear River Basin water balance parameters as percent of precipitation.^b

WATER BALANCE PARAMETERS ^a	% of Precipitation
Net stream outflows ^c	11.68%
Evaporation from reservoirs ^d :	0.38%
Water exported (Surface water depletions from municipal/domestic, livestock, and industrial uses) ^d	0.19%
Water exported (Groundwater depletions from municipal/domestic, livestock, and industrial uses) ^d	0.11%
Total estimated Bear River Basin recharge (Table 6-3)	13.52%
Basin-wide evapotranspiration	74.12%
Total	100.00%

^aFetter, C. W., 2001

^bPRISM Climate Group, 2012

^cUSGS, 2012

^dWyoming Water Development Office, 2012

Table 8-2c. Summary of groundwater use statistics as percentage of recharge in the Wyoming portion of the Bear River Basin.

Groundwater-use statistics	Annual volume (acre-feet)	Percentage of calculated recharge
¹ Total estimated recharge (acre-feet)	188,968	-----
³ Average annual groundwater withdrawals		
² Agricultural uses (irrigation and stock watering)	2,400	1.3%
² Municipal & domestic	1,334	0.7%
² Industrial	5	0.003%
² TOTAL	3,739	2.0%

consumptive uses for agricultural, municipal, rural domestic and industrial uses in 2030. The analysis examines normal and maximum water demand cases for low and high economic growth scenarios. Projected future annual groundwater requirements for the 30-year timeframe are determined as percentages of annual recharge estimated in **Chapter 6**.

Overall groundwater demands projected for 2030 range from 3 percent of recharge for low growth / normal demand, to 6 percent for high growth / high demand conditions. So it appears that estimated recharge volumes are adequate to meet not only current withdrawals (**Table 8-2c**) but future groundwater demands, as well. However, these analyses do not consider legal constraints imposed by the Amended Bear River Compact that may limit future groundwater development. The potential for overutilization of groundwater resources is

location-specific, both hydrologically and legally, and must be evaluated during the planning stage of any development project. Evaluating potential groundwater resources of the Bear River Basin outside of existing environmental regulations and legal restrictions is beyond the scope of this study.

8.5 Groundwater withdrawals by use

The following sections discuss the uses that account for nearly all estimated groundwater withdrawals in the 2001 and 2011 Bear River Basin Water Plans (Forsgren and Associates, 2001; WWDO 2012) and the 2007 Statewide Framework Water Plan (WWC Engineering and others, 2007). Tables 8-6 through 8-8 show the number of groundwater permits by use for the portions of Wyoming, Utah, and Idaho, respectively, that fall within the boundaries of the Bear River Basin examined in this

Table 8-2d. Summary of future groundwater requirements as percentages of recharge

Economic scenario	Low growth			High growth		
¹ Water demand scenario	Normal demand		High demand	Normal demand		High demand
Groundwater demand - 2030 total withdrawals (acre-feet)	6,518	-	8,860	7,963	-	10,675
Percentage of estimated recharge	3.4%	-	4.7%	4.2%	-	5.6%
Groundwater demand - 2030 consumptive use (acre-feet)	2,646	-	3,433	3,580	-	4,535

report (**Figure 3-1**). The “other” category includes miscellaneous wells.

8.5.1 Irrigation

Direct measurements of groundwater volumes used for irrigation are not presented in either the 2001 or 2011 Bear River Basin final report (Forsgren and Associates 2001; WWDO 2012) or in the 2007 State Framework Water Plan (WWC Engineering and others, 2007). Instead, estimates of irrigation uses for combined surface water and groundwater based on water use factors were developed using crop-specific information from 1971 through 1998. From these, total diversions and consumptive uses were generated for four cases formulated from low and high economic growth scenarios within the context of both normal and maximum water demand conditions determined for the year 2001 (Forsgren and Associates, 2001). The same procedure was used to predict total irrigation diversions and consumptive uses for the year 2030. The 2001 study estimated the proportions of groundwater and surface water that constitute total withdrawals and consumptive use for all evaluated uses. Groundwater withdrawals and consumptive volumes were then back-calculated for all uses; see **Tables 8-1a** and **8-2d** (Forsgren and Associates, 2001).

In the Bear River Basin, most irrigation wells are located along the river and its tributaries where water is obtained from the relatively shallow Bear River Alluvium. Irrigation uses are partially consumptive due to crop ET; consumptive uses are estimated at 80 percent of total withdrawals for irrigation (Forsgren and Associates, 2001; WWDO 2012). Within the Bear River Basin, 43 SEO and 47 Utah Division of Water Resources (UDWR) permits have been issued solely for irrigation use. Updated data for total permits and permitted yields from the SEO, UDWR, and IDWR is shown in **Tables 8-6** through **8-8** and in **Figure 8-1**.

8.5.2 Livestock watering

Withdrawals and consumptive uses for livestock watering were estimated in the 2001 Water Plan (Forsgren and Associates, 2001) at 528 ac-ft/

yr (**Table 8-2c**) using stock-specific daily water requirements of 12 gal/day/animal for cattle and 2 gal/day/animal for sheep. It was assumed that all of the water used for livestock watering is consumptively used surface water. The 2011 Water Plan estimated that livestock consumptive use was 350 ac-ft per year drawn from both surface and groundwater sources but did not assign a use value specific to groundwater (WWDO 2012). Irrigation and livestock groundwater consumptive uses, aggregated in the summary section of both reports as agricultural uses, were listed at 1,900 ac-ft per year. In the Bear River Basin, 215 SEO permits and 115 UDWR permits have been issued solely for stock watering (**Tables 8-6, 8-7, and 8-8**).

8.5.3 Municipal/community public water systems

Municipal/community public water systems supply water year-round to essentially the same population (<http://www2.epa.gov/region8-waterops>). **Chapter 5** of the 2011 Water Plan (WWDO 2012) contains groundwater use information for community public water systems from the Water System Survey Report (WWDO 2009), the EPA Public Water System database (<http://www2.epa.gov/region8-waterops>), and directly from water system operators and administrators. For systems that otherwise lacked information, average and peak use volumes were calculated by multiplying per capita values obtained from well documented systems (Evanston, Cokeville, and Bear River) by the population served. Average annual municipal use of groundwater in the Bear River Basin is summarized by communities that obtain all or part (conjunctive use of surface and groundwater sources) of their supply from groundwater in Section 5.3 and Tables 5-8 through 5-17 of the 2011 Bear River Basin Water Plan (WWDO 2012). Community (municipal) groundwater total withdrawals noted in Table 5-16 of the 2011 plan are summarized in **Table 8-1c** of this report. Consumptive use of combined community and domestic groundwater withdrawals is reported in the 2011 Bear River Basin Water Plan (WWDO 2012) at 80 percent of the above total withdrawal estimates.

Municipal/community use constitutes a relatively small part of overall groundwater consumptive uses in the Bear River Basin (**Table 8-2a**). As of February 27, 2012, the SEO issued 8 permits for exclusive municipal use in the Bear River Basin (**Table 8-6**). In addition to the municipal use permits, many of the wells that supply water to the basin's municipalities and communities (**Tables 8-9 through 8-11**) are permitted as multiple use or miscellaneous wells.

8.5.4 Rural domestic use

Rural domestic withdrawals are defined as household uses that are not supplied by municipal water systems. Nearly all rural domestic supplies are drawn from groundwater. Rural domestic use was determined by calculating rural population size (municipal population subtracted from basin population, (Wyoming Economic Analysis Division, 2008) and then multiplying by an average per capita withdrawal rate of 180 gallons per day (WWDO 2012). The per capita use rates were obtained from the 2001 Bear River Basin Water Plan (Forsgren and Associates, 2001). Average rural domestic water usage was estimated at 533 ae-ft/yr (**Table 8-1c**). The consumptive use rate was assumed to be 100 percent of domestic groundwater withdrawals.

Rural domestic use constitutes a small part of overall groundwater withdrawals in the Bear River Basin (**Table 8-2a**). Actual rural domestic withdrawals are much less than the amounts projected from SEO permitted yields because domestic wells are typically used intermittently while SEO projections assume continuous use. In addition, it is likely that some of the permits are inactive. The mapped distribution of domestic permits in the Bear River Basin (**Figure 8-4**) indicates that most rural domestic wells are completed in the Bear River alluvium. Domestic wells are also completed in basin's principle bedrock aquifers, while a smaller number are completed in confining units. **Tables 8-6 through 8-8** indicate that, in the Bear River Basin, 418 domestic wells permits have been issued in Wyoming, 416 in Utah and one in Idaho (the only Idaho permit listed for any use in that portion of the Bear River Basin considered in this study).

8.5.5 Combined municipal and domestic withdrawals and consumptive use

Table 6-4 in the 2011 Water Plan (WWDO 2012) contains projections of municipal and rural domestic groundwater uses as part of an economic study of future groundwater demands for the Bear River Basin (**Table 8-2d**). The study projected that combined Wyoming annual municipal and domestic consumptive uses of surface water and groundwater would reach 2,703 and 1,326 acre-feet, respectively by 2030. According to these projections, consumptive uses would increase by only 8 – 9 percent over 2009 levels. Total municipal and rural domestic withdrawals from groundwater were estimated at about 25 percent of total diversions. Based on the difference between municipal diversions and effluent discharge, consumptive use of surface water and groundwater was estimated at approximately 59 and 92 percent of withdrawals, respectively. The higher rate of consumptive use for groundwater is due, in part, to the assumption that all water withdrawn from rural domestic wells is used consumptively.

8.5.6 Recreational and environmental uses

Although water in Wyoming has been developed primarily to provide supplies for irrigation, flood control, and for hydroelectric power generation, recreational uses must also be considered. The majority of recreational water use is associated with surface water bodies (swimming, fishing, camping, hunting, and boating) and snow (skiing and snowmobiling); although these activities are non-consumptive, they do rely on adequate and consistent water sources. Only a few recreational uses, such as snowmaking and turf irrigation, are consumptive. The Bear River Basin 2011 Water Plan (WWDO, 2012) did not estimate how much groundwater is used for recreation, but noted that growing recreational uses are important in the Bear River Basin and should be considered during future project planning.

The Bear River Basin 2011 Water Plan (WWDO 2012) discusses environmental water uses such as

maintaining minimum stream flows and reservoir water levels to protect wildlife habitat and fisheries. Specifically, these include surface water withdrawals required to meet SEO in-stream flow filings, U.S. Forest Service instream bypasses, and voluntary minimum levels for US Bureau of Reclamation reservoirs designed to produce and protect fisheries habitat that historically have been impacted by low flow conditions. Consumption of water for environmental uses is minimal and due primarily to evaporative loss. Except for groundwater discharges to surface waters, which are undetermined, environmental uses of groundwater are not addressed.

8.5.7 Industrial uses (WWDO, 2012)

The 2011 Bear River Basin Water Plan (WWDO 2012) identified the most important industrial water users and estimated current groundwater withdrawals by industrial facilities (**Table 8-1b**). Industrial applications use minimal amounts of groundwater in the Bear River Basin (**Table 8-2c**). Chevron and BP Amoco are the primary industrial consumers of groundwater in the Bear River Basin. Industrial consumptive uses of water, primarily for gas processing, are limited to about 47 acre-feet per year, of which 5 acre-feet consist of groundwater. The remainder is drawn from surface water sources (WWDO 2012).

To quantify industrial water use, the authors of the 2011 Bear River Basin Water Plan (WWDO 2012) evaluated SEO permit information for industrial and miscellaneous uses, and conducted follow up interviews and written surveys of permit holders. The 2011 Water Plan (WWDO 2012) provides details on industrial groundwater use within the Bear River Basin. An examination of updated records on the SEO database for this study found that as of February 27, 2012, 11 groundwater permits for industrial operations had been issued in the Bear River Basin (**Table 8-6**).

Chapter 6 of the 2011 Bear River Basin Water Plan predicted that industrial uses of groundwater may increase to 15 acre-feet per year by 2030 under a high economic growth scenario. Otherwise, under

a low growth scenario, industrial groundwater use is expected to drop to zero by 2030.

Discharges of groundwater withdrawn as a byproduct during conventional oil and gas production are not required to be permitted with SEO and were estimated from WOGCC information compiled for this study. Records of produced water injection were also obtained from the WOGCC (**Table 8-1b**). An average of 466 ac-ft of groundwater was generated annually from 2003 through 2012 during oil and gas production, and an average of 222 ac-ft/yr of produced water was injected over the same time. In contrast to groundwater withdrawn during conventional oil and gas production, groundwater produced during coal bed natural gas (CBNG) operations is regulated by the SEO and WDEQ. No SEO permits for CBNG wells have been issued for the Bear River Basin and WOGCC records confirm that there are no current groundwater withdrawals for CBNG in the Bear River Basin.

Groundwater withdrawn for industrial, fuels, and non-fuels mining applications may be of naturally poor quality and in some cases industrial processes degrade water quality. Most industrial groundwater that is not initially used consumptively is either discharged to the surface (sometimes after treatment) under a Wyoming Pollution Discharge Elimination System WYPDES permit issued by WDEQ, injected for permanent disposal, or reused for enhanced oil and gas production. Some industrial wastewater, including water coproduced with oil and gas, is evaporated at permitted disposal reservoirs. In some cases industrial wastewater is reused for general industrial purposes such as dust control. Because produced water from oil and gas operations is a byproduct, it probably would not be withdrawn for any other purpose. Injecting produced water for enhanced oil and gas recovery or permanent disposal into aquifers generally too deep to be considered for groundwater development effectively removes water from the system and is, therefore, consumptive.

Produced water withdrawal and injection volumes were not included on either side of the water balance equation in this report but were provided on

Table 8-1b for the reader's information. A review of industrial discharges under the authority of WYPDES permits indicates that there are three industrial WYPDES permits: one for the Painter Natural Gas Plant now owned by Merit Energy and two permits for travel centers (restaurants and refueling stations for travelers and the trucking industry). The wastewater from the natural gas plant is discharged to a sedimentation pond and then ultimately re-injected. One WYPDES permit for the Kemmerer Mine, owned by Chevron Mining, lists one outfall which discharges to the Bear River Basin; the other seven outfalls discharge to the Green River Basin. The discharges are composed of treated pit water and storm runoff from disturbed areas. Discharges from these permits are small and were not considered in the water balance presented in this chapter.

8.6 Information from hydrogeologic unit studies

In addition to the withdrawal and consumptive use data compiled from previous state water plans, aquifer-specific groundwater use information was compiled from a variety of sources for the discussion in **Chapter 7** of hydrogeologic units in the Bear River Basin. **Chapter 7** summarizes the physical, hydrogeologic, and chemical characteristics of the principal hydrogeologic units in the Bear River Basin including the known dynamics of recharge, discharge, and groundwater circulation.

Appendix B provides a chronological summary of the locations, aquifers, focus, results, and status of groundwater development studies that have been sponsored by the WWDC since 1973 in the Bear River Basin. Many of these studies were used to compile the information presented in **Chapter 7**.

8.7 Groundwater permit information

Groundwater development proceeds primarily by installing water supply wells and, to a lesser degree, by developing natural springs. Permits allowing the appropriation of groundwater are issued and administered by the SEO in Wyoming, the Department of Water Resources (IDWR) in Idaho, and the Division of Water Rights (UDWR) in Utah.

For this study, the WSGS acquired groundwater permit data from all three agencies. The SEO provided information for 1,362 groundwater permits through February 27, 2012, including 315 newer permits issued after December 31, 2000 (**Tables 8-3** and **8-6**). UDWR provided data for 981 Utah groundwater permits through September 20, 2012. Data was obtained on one Idaho groundwater permit from the IDWR through September 20, 2012 in the Idaho part of the Bear River Basin (**Table 8-8**). Limitations and other characteristics of the groundwater-permits databases are described in **Appendix C**. Information for specific SEO groundwater permits can be accessed through the SEO online water rights database at: http://seo.state.wy.us/wrdb/PS_WellLocation.aspx. The database is easy to use and specific information can be queried using various search parameters (e.g., permit number, location, applicant, use).

Groundwater permit information from the UDWR can be accessed at: <http://maps.waterrights.utah.gov/mapserver/scripts/search.asp>

Information on specific groundwater permits from the IDWR can be accessed at: <http://www.idwr.idaho.gov/WaterManagement/default.htm>. Permits to appropriate groundwater in the Bear River Basin have been mapped for this study and certain data has been tabulated in formats that are highly informative. The maps of permit locations by use contained in **Chapter 8** illustrate the spatial distribution of particular types of groundwater wells throughout the Bear River Basin. Groundwater permit data is tabulated in this section to summarize the number of permits by:

1. SEO permit status, depth range, and yield range;
2. Class of use (SEO, UDWR, IDWR);
3. SEO municipal use, including producing hydrogeologic unit;
4. WDEQ Source Water Assessment Program (SWAP).

In addition, permit data are tabulated on maps depicting locations of likely drilled wells (**Figures 8-1** through **8-6**). SEO data are tabulated and mapped in this study for all permits through February 2012

Table 8-3. SEO groundwater permits in the Bear River Basin listed by permit status.

Permit Status	All Permits through 2000	New Permits since 2001
Fully Adjudicated	50	6
Complete	850	139
Unadjudicated	0	5
Incomplete	60	79
Undefined	87	86
<i>Total Permits</i>	<i>1,047</i>	<i>315</i>
<i>Probable Wells Drilled</i>	<i>900 - 987</i>	<i>150 - 236</i>
	<i>(86 - 91%)</i>	<i>(48 - 75%)</i>

and for permits from 2001 through February 2012 to illustrate development over the last decade.

8.7.1 Groundwater permits by permit status

Table 8-3 shows the number of groundwater permits issued by the SEO under eight permit-status categories. **Table 8-3** does not include permits from either the UDWR or the IDWR. In Wyoming, the status categories are:

1. *Fully Adjudicated* – the well has been drilled and inspected, and a certificate of appropriation issued.
2. *Complete* – SEO has received a notice of completion of the well.
3. *Unadjudicated* – the well has not yet been inspected but may have been drilled.
4. *Incomplete* – SEO has not received a notice of completion of the well.
5. *Undefined* – a permit without a designated status. These include the following discontinued status categories:
 - *Abandoned* – SEO has received a notice that the well has been physically abandoned.
6. *Expired* – the permit to appropriate groundwater has expired, generally because SEO has not received a notice that the well has been completed within the time period specified in the original permit or extension(s).

7. *Cancelled* – the permit has been cancelled, generally by the original permit applicant.

The SEO issues permits granting water rights to applicants. This does not necessarily mean that a well has been completed and in most cases, it is not known with any certainty whether a well was installed in association with a specific permit. To estimate the number of wells that have likely been completed for each use, the Wyoming State Geological Survey (WSGS) assumed that wells probably have been completed for fully adjudicated, complete, abandoned and unadjudicated permits. In contrast, wells are likely not completed in association with incomplete and undefined permits. **Table 8-3** summarizes the number of likely drilled wells for each use in the Bear River Basin. Based on these assumptions, at least 86 percent of wells permitted through 2000 are likely to have been installed (i.e., completed) compared to at least 48 percent of wells permitted since 2001.

8.7.2 Groundwater permits by depth and yield

Table 8-4 shows the number of permits by depth range and **Table 8-5** shows the number of permits by yield range. **Tables 8-4** and **8-5** do not include permits from the UDWR or the IDWR.

Approximately 99 percent of all SEO groundwater permits for which depth data are available are for wells less than 500 feet deep, and approximately 92 percent are for wells less than 100 feet deep.

Table 8-4. SEO groundwater permits in the Bear River Basin listed by depth range.

Depth Range(feet)	All Permits		Cumulative	
	Permits	Percentage	Permits	Percentage
1-50	800	79.37%	800	79.37%
51-100	125	12.40%	925	91.77%
101-500	73	7.24%	998	99.01%
501-1000	6	0.60%	1004	99.60%
> 1000	4	0.40%	1008	100.00%
Total Permits with Depth information	1008	--	--	--
Permits with no Depth information	354	25.99%	1362	--
Total Permits	1362	(of Total)	--	--
Depth Range(feet)	New Permits since 2001		Cumulative	
	Permits	Percentage	Permits	Percentage
1-50	117	80.69%	117	80.69%
51-100	18	12.41%	135	93.10%
101-500	10	6.90%	145	100.00%
501-1000	0	0.00%	145	100.00%
> 1000	0	0.00%	145	100.00%

All SEO groundwater permits issued from 2001 through February 2012, were for wells less than 500 feet deep, and approximately 93 percent were for wells less than 100 feet deep. In the SEO database, many of the permits (54 percent issued after 2001 and 26 percent overall) do not include well depth.

Of the 1,185 groundwater permits in the Bear River Basin database for which yield information is available, approximately 90 percent are permitted for yields of 0-25 gpm both for permits issued after 2001 and for total permits. Less than three percent of permits issued after 2001 and less than 2 percent of total permits are for yields greater than 1,000 gpm. Approximately seven percent of both types of permits (issued after 2001 and total permits) have been issued for yields greater than 100 gpm. Many of the permits (13 percent issued after 2001 and 17 percent overall) in the SEO database do not include permitted yield.

Permitted depths and yields, and the mapped permit locations on **Figures 8-1** through **8-6** illustrate that most wells in the Bear River Basin are planned and completed in near-surface, Quaternary hydro-geologic units.

8.7.3 Groundwater permits by use: tables, figures, and matrix tables

Groundwater permit information, by use, is presented in **Tables 8-6** through **8-8** and **Figures 8-1** through **8-6**, and the matrix tables contained in the figures. This information was obtained from the SEO, the UDWR, and the IDWR. All of these agencies issue permits granting water rights to applicants. In many cases, especially with older permits, it is not known with any certainty whether a well or spring improvement was actually installed in association with a specific permit. Furthermore, existing facilities might have been abandoned after some time and are no longer being used beneficial-

Table 8-5. SEO groundwater permits in the Bear River Basin listed by yield range.

Yield Range(gpm)	All Permits		Cumulative	
	Permits	Percentage	Permits	Percentage
1-25	1070	90.30%	1070	90.30%
26-100	38	3.21%	1108	93.50%
101-500	36	3.04%	1144	96.54%
501-1000	22	1.86%	1166	98.40%
> 1000	19	1.60%	1185	100.00%
Total Permits with Yield information	1185	--	--	--
Permits with no Yield information	177	13.00%	1362	--
Total Permits	1362	(of Total)	--	--
Yield Range(gpm)	New Permits since 2001		Cumulative	
	Permits	Percentage	Permits	Percentage
1-25	235	89.69%	235	89.69%
26-100	9	3.44%	244	93.13%
101-500	5	1.91%	249	95.04%
501-1000	7	2.67%	256	97.71%
> 1000	6	2.29%	262	100.00%
Total Permits with Yield information	262	--	--	--
Permits with no Yield information	53	16.83%	315	--
Total Permits	315	(of Total)	--	--

ly. Any examination of permitted uses must explain how the permit data was processed and what it actually represents. The permit data presented in the following two sections differs between the figures and the tables:

- **Tables 8-6, 8-7, and 8-9** show the number of groundwater permits issued in Wyoming, Utah, and Idaho, respectively, by permitted use regardless of permit status (**Section 8.4.1**). This means that all permits issued are listed without evaluating if a well was installed. The tables list six single primary use categories (municipal, domestic, industrial, irrigation, stock, and monitoring), an “other” category for all other single uses, and a “multi-use” category for permits that list more than one use. (Approximately 30 percent of all groundwater permits in the Bear River Basin are for multiple uses). The “other”

category includes permits issued for “miscellaneous uses,” and minor uses such as test wells. The number of permits given for a single use (e.g., eight total permits for municipal use in **Table 8-6**) includes neither “multi-use” permits which may allow municipal use in addition to other uses nor those permits listed as “other” which may allow municipal withdrawals. Additionally, values for “total permitted yield” calculated by summation of all permits with listed yields and “total likely yield” determined by analysis of permit status are provided.

- **Figures 8-1 through 8-6** show the number of “likely drilled wells”, determined by analysis of permit status (**Section 8.4.1**) for each of the six primary use categories (municipal, domestic, industrial, irrigation, stock, and monitoring). This includes permits where one use is listed. For example, the number of municipal wells is

determined by counting single use “municipal” wells and any “multi-use” permits which include “municipal” as one of the permitted uses. Thus, multi-use wells are counted several times, once for each listed use.

- Matrix tables contained in each of the figures, present the number of all permits issued for each use combined in all three states (**Figure 3-1**) regardless of permit status. This includes permits where one use is listed, for example “municipal” as well as “multi-use” permits which include “municipal” as one of the permitted uses.

8.7.3.1 Groundwater permits by use: Tables 8-6, through 8-11

Tables 8-6, 8-7, and 8-8 show that most groundwater permits in the Bear River Basin are for domestic use at individual residences, followed by multi-use, and stock wells.

Additionally, total likely yields (permitted yields from wells that are likely to be completed) constitute a fraction of the total permitted yields. A comparison of total likely yields to total permitted yields for each use suggests that a higher proportion of domestic and stock wells were completed and used beneficially than any other type of wells.

Tables 8-9 and 8-10 are expanded summary tables for SEO permits that include municipal uses, and **Table 8-11** summarizes information on SWAP wells and springs that are used for both municipal and non-community public water supply. A brief discussion of the SWAP is provided in **Section 8.4.3.7**. The SWAP provides some information beyond what is available in the SEO groundwater permits data.

8.7.3.2 Groundwater permit location maps and matrix tables, by use

Six maps (**Figures 8-1 through 8-6**) were prepared for this study to illustrate the geospatial distribution of groundwater permits according to use in the Bear River Basin. Only permits for wells that were likely to have been drilled (including abandoned wells) are included on **Figures 8-1 through 8-6**. Groundwater permits are mapped relative to their date of issue (before or after January 1, 2001) on Bear River Basin scale maps and by total well depths on subregion scale figures. Figures have been provided for the following permitted uses:

- Irrigation (**Figure 8-1**)
- Livestock (**Figure 8-2**)
- Municipal (**Figure 8-3**)
- Domestic (**Figure 8-4**)
- Monitoring (**Figure 8-5**)

Table 8-6. SEO groundwater permits in the Bear River Basin listed by intended use.

	WSEO	Total Number	New Since	Total Permitted Yield	Total Likely Yield*
Well Type	Code	of Permits	2001	(gpm)	(gpm)
Municipal	MUN	8	2	4,150	100
Domestic	DOM	418	107	6,723	5,185
Industrial	IND	11	0	1,764	0
Irrigation	IRR	43	10	36,406	7,190
Stock	STK	215	53	3,511	2,611
Monitor	MON	147	45	1	1
Other	MIS, blank	112	21	4,169	1,189
Multi-Use	various	408	77	22,970	6,639
Total		1,362	315	79,693	22,915

*Includes only wells that are Fully Adjudicated, Complete, and Unadjudicated.

Table 8-7. Utah DWR groundwater permits in the Bear River Basin listed by intended use.

Well Type	Total Number of Permits	New Since 2001	Total Permitted Yield (gpm)
Municipal	11	6	2,265
Domestic	416	126	1,973
Industrial	0	0	0
Irrigation	47	6	35,525
Stock	144	17	2,147
Monitoring	0	0	0
Other	134	4	7,380
Multi-use	229	37	53,880
Total	981	196	103,170

- Miscellaneous-use and other wells (**Figure 8-6**)
- USGS spring locations are shown on **Plate 3**

Industrial permit wells were not mapped because there are relatively few of them (**Table 8-6**), and they withdraw and consume minor amounts of groundwater (**Table 8-1b**).

Figures 8-1 through **8-6** differentiate groundwater permits issued from January 1, 2001 through February 27, 2012 in order to evaluate how groundwater development in the Bear River Basin has proceeded during the past decade. Substantial groundwater development has occurred in the Bear River Basin since the 2001 Groundwater Determination (Forsgren and Associates, 2001). Consistent with the historic trend, it is clear that most permits issued over the 2001 – 2012 period in the Bear

River Basin continue to target Quaternary and Tertiary hydrogeologic units.

Matrix tables that correlate ranges of well depths and yields for all permits issued are also provided on the groundwater permit maps. Consistent with **Tables 8-4** and **8-5**, the depth vs. yield tables shows that by far the most permits issued in the Bear River Basin are for 0-25 gpm across all depth ranges. In addition, the insert tables show that fewer wells are permitted for increasingly higher yields across all depth ranges. Because only permits for wells that were likely to have been drilled (status of fully adjudicated, complete, unadjudicated, and abandoned) are shown on **Figures 8-1** through **8-6**, the number of permits on the insert matrix tables does not match the number of permits depicted on the maps.

Table 8-8. Idaho DWR groundwater permits in the Bear River Basin listed by intended use.

Well Type	Total Number of Permits	New Since 2005	Total Permitted Yield (gpm)
Municipal	0	0	0
Domestic	1	0	5
Industrial	0	0	0
Irrigation	0	0	0
Stock	0	0	0
Monitoring	0	0	0
Other	0	0	0
Multi-use	0	0	0
Total	1	0	5

Figure 5-11 shows the distribution of SWAP wells that are used for municipal and other public supply. Because public supply is one of the most important uses of groundwater resources, a more comprehensive compilation was performed for the SEO permit data and related WDEQ SWAP data on municipal and non-community public groundwater supplies.

8.7.3.3 Irrigation use permits (Figure 8-1)

Tables 8-6 through **8-8** list 90 groundwater permits for irrigation use (IRR) in the Bear River Basin, with 43 in Wyoming and 47 in Utah. **Figure 8-1** shows the distribution of likely drilled irrigation wells in the entire Bear River Basin, issued before and after January 2001. Most irrigation wells are located in rural areas and along rivers and other surface drainages where Quaternary hydrogeologic units provide adequate groundwater for this high-volume use. The depth vs. yield tables on **Figure 8-1** show that while permits have been issued for all depth categories, most irrigation well permits that list depth were permitted for depths of less than 50 feet, across a wide range of yields for both total permits and permits issued since January 2001. Most irrigation permits have no recorded depth information. **Tables 8-6** through **8-8** and the matrix tables in **Figure 8-1** illustrate that a relatively small fraction of the total number of permits in the Bear River Basin have been issued since 2001, as development may be limited in many places by the legal constraints discussed previously in this chapter, in **Chapter 1**, and in **Appendix D**. **Figure 8-1** illustrates that most permits appropriate water from wells located near the Bear River, likely targeting alluvial deposits adjacent to the river.

8.7.3.4 Livestock use permits (Figure 8-2)

Tables 8-6 through **8-8** show that 215 SEO permits and 144 UDWR permits groundwater permits have been issued solely for livestock use (STK), a quantity exceeded only by the number of domestic use and multi-use permits in the Bear River Basin. **Figure 8-2** shows the distribution of likely drilled stock wells in the Bear River Basin is-

sued before and after January 2001. Stock wells are located throughout the Bear River Basin, especially along the Bear River and its tributaries. Although, most stock wells are completed in Quaternary hydrogeologic units, some are completed in outcrops of Tertiary to Mesozoic aquifers and confining units located in areas along basin uplands. The depth vs. yield tables on **Figure 8-2** show that the largest number of total permits and permits issued since 2001 are for depths of 100 feet or less and for yields of up to 100 gpm. Many permits for stock watering have no recorded depth information.

8.7.3.5 SEO municipal use permits (Figure 8-3)

Tables 8-6 and **8-7** show that there are 19 groundwater permits issued solely for municipal use (MUN) in the Bear River Basin with 8 permits issued in Wyoming (**Table 8-6**) and 11 permits issued in Utah (**Table 8-7**). **Figure 8-3** shows the spatial distribution of likely drilled municipal wells. Most municipal permits do not contain depth data. No municipal-use permits were listed in the IDWR data.

Tables 8-9 and **8-10** distinguish 13 municipal use groundwater permits on file with the SEO by status. **Table 8-9** summarizes selected information on six municipal-use permits that have been fully adjudicated; all of these permits, with the exception of P186463 (administrative enlargement of P110471W), were issued before January 2001. **Table 8-9** includes available information on permitted yield, well depth, depth of the producing interval, and the producing hydrogeologic unit. Three of the permits in **Table 8-9** are for multiple uses. Because the “fully adjudicated” permit status indicates that the well has been inspected, the information in **Table 8-9** is presumed to be fairly accurate. The wells in **Table 8-9** produce water from bedrock aquifers, (**Plate 2**). Information on producing intervals was obtained from SWAP data, WWDC consultant reports, and SEO data.

Table 8-10 summarizes selected information on seven SEO municipal well permits listed as incomplete or complete, or do not have a status listed. **Table 8-10** includes available information on

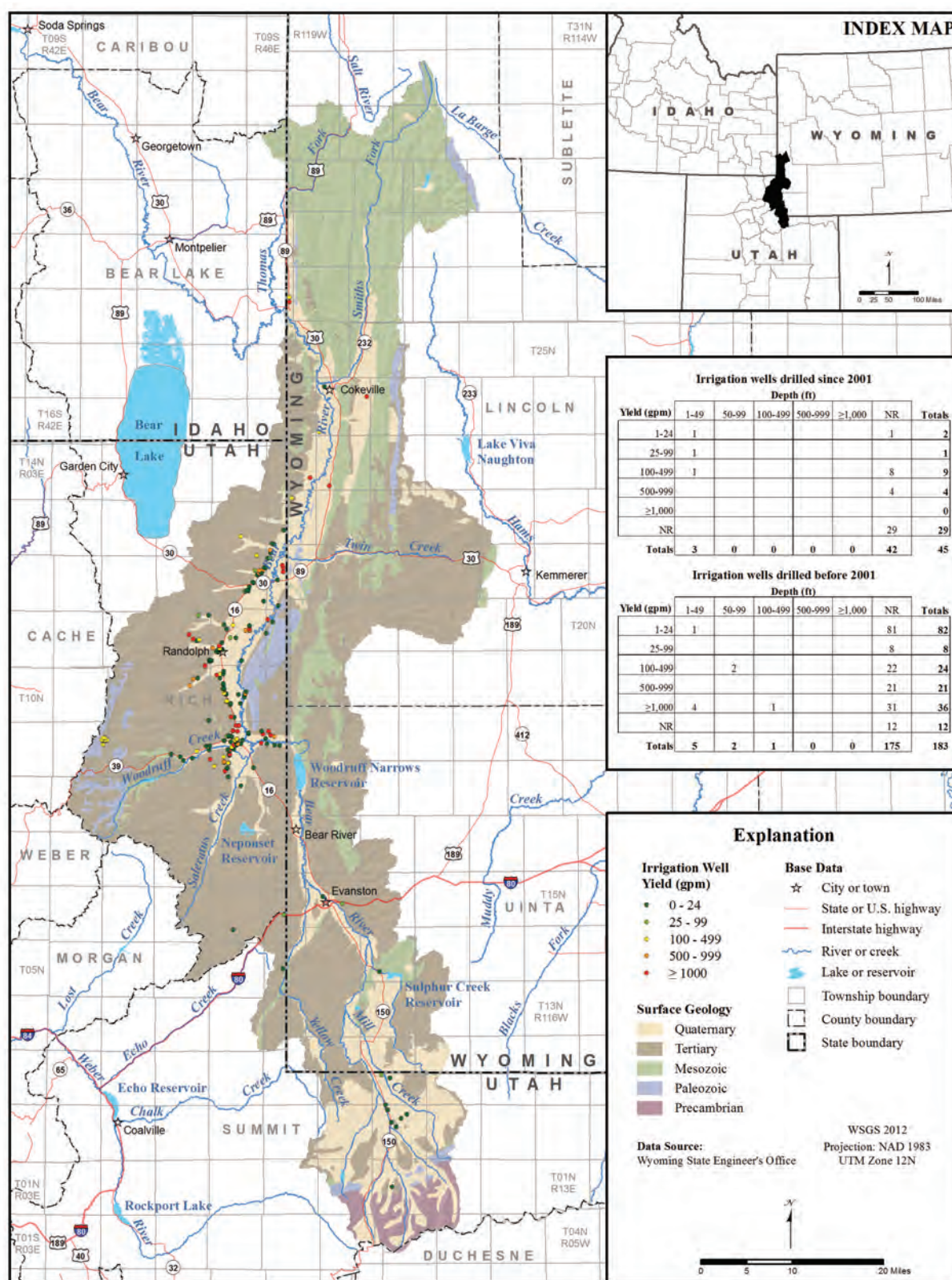


Figure 8-1. Wyoming SEO, Utah DWR, and Idaho DWR permitted and drilled irrigation wells, Bear River Basin.

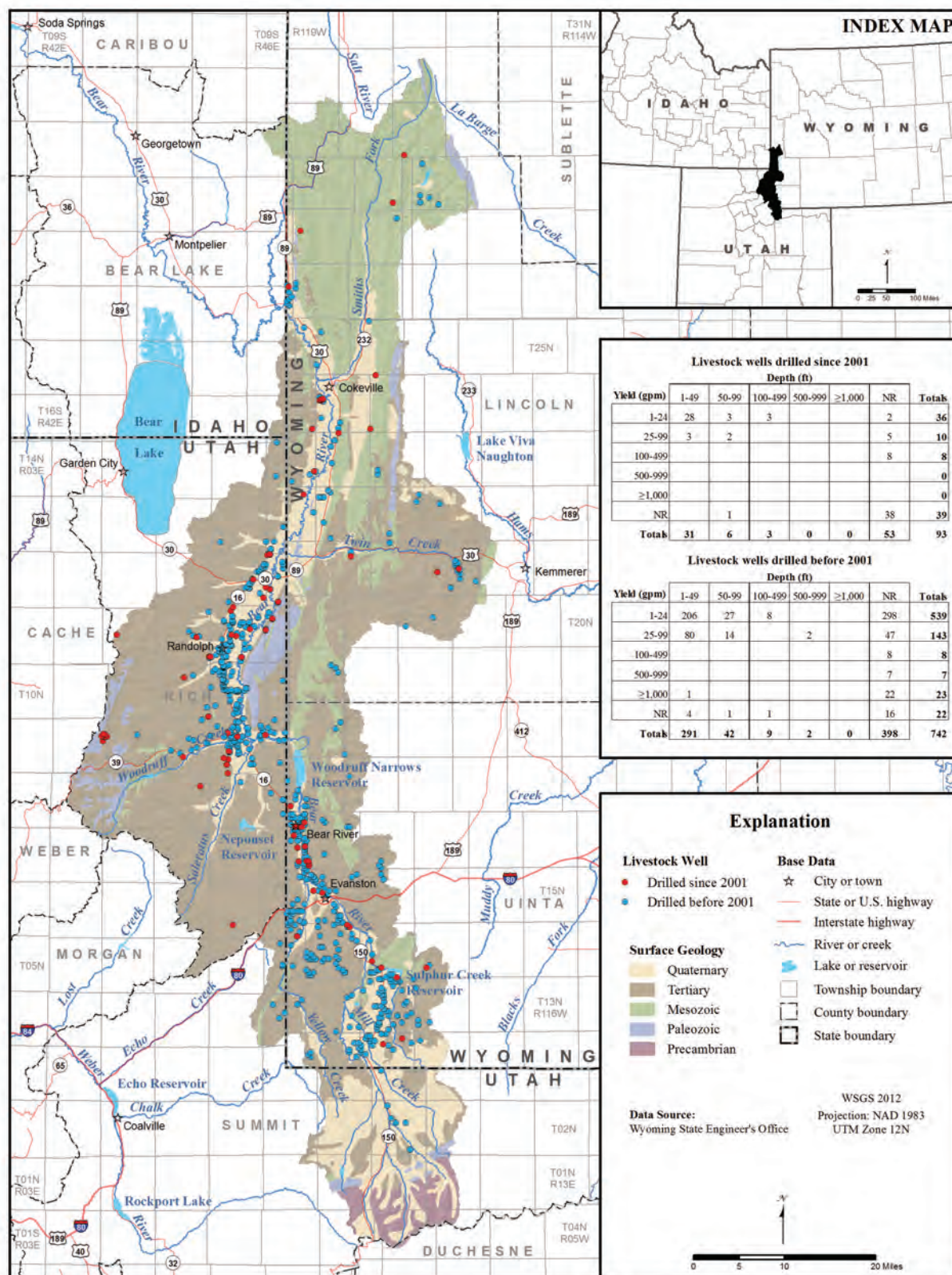


Figure 8-2. Wyoming SEO, Utah DWR, and Idaho DWR permitted and drilled livestock wells, Bear River Basin.

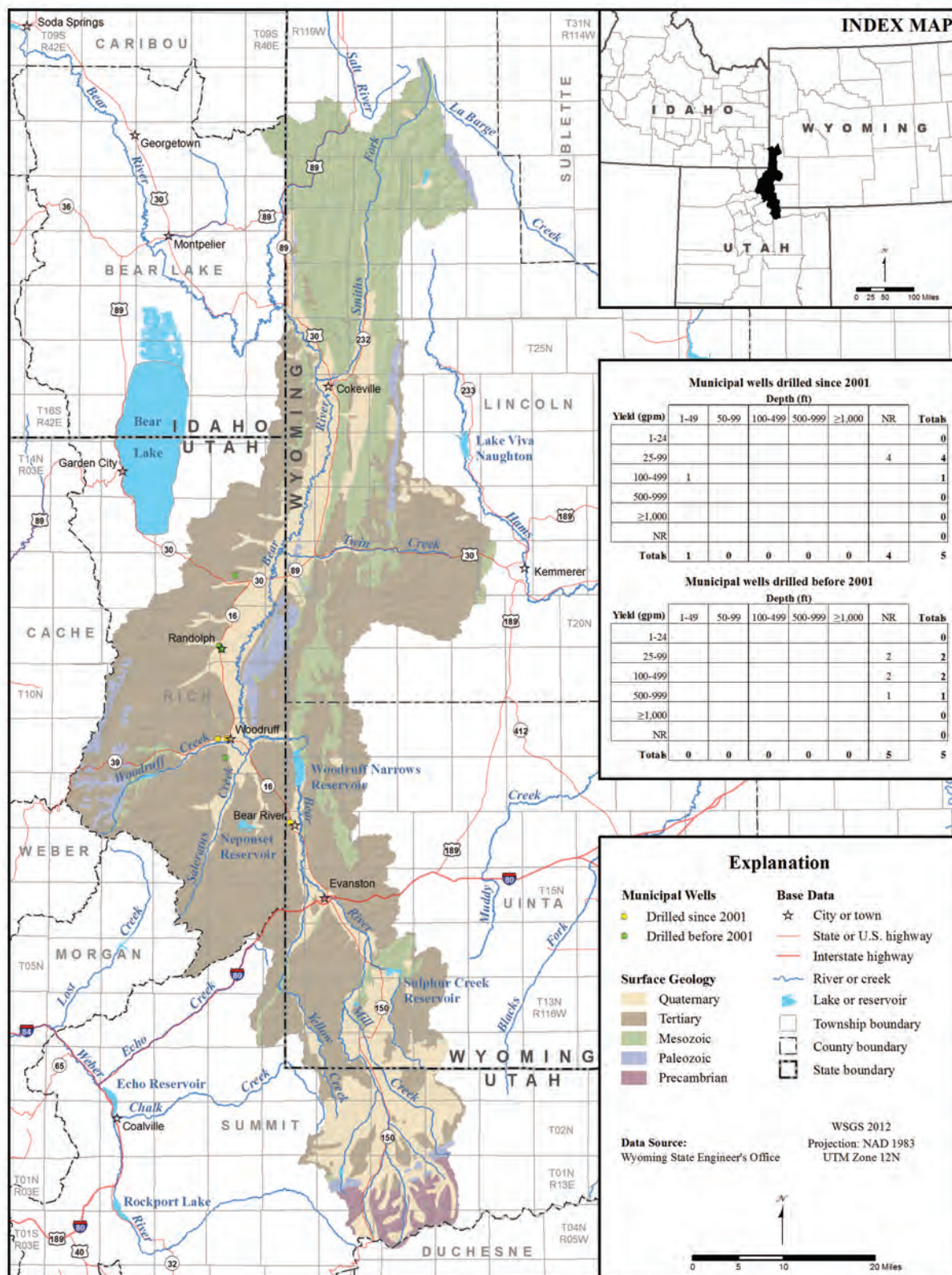


Figure 8-3. Wyoming SEO, Utah DWR, and Idaho DWR permitted and drilled municipal wells, Bear River Basin.

Table 8-9. SEO fully adjudicated municipal well permits in the Bear River Basin.

Municipality or Community	Well Name	Permit Number	yield (gpm)	Depth (feet)	Permit Status	geologic unit	(feet)
Bear River	Deer Mountain #1	P65876W	26	350	Fully Adjudicated	Wasatch Fm	320-350
Bear River	Hoback Ranches #5	P84238W	25	760	Fully Adjudicated	Wasatch Fm	660-760
Bear River	Hoback Ranches #2	P84240W	25	390	Fully Adjudicated	Wasatch Fm	320-340
Cokeville	Cokeville #2	P110471W	450	173	Fully Adjudicated	Thomas Fork Fm	yes 72-119
Cokeville	Enl. Cokeville Well No. 2	P186463.0W	600	173	Fully Adjudicated	Thomas Fork Fm	yes 72-119
Cokeville	Cokeville #3	P110472W	700	175	Fully Adjudicated	Thomas Fork Fm	yes 144-173

permitted yield and well depth. All of the permits in **Table 8-10** are for multiple uses. The wells in **Table 8-10** produce water from alluvial and bed-rock aquifers, (**Plate 2**).

While cancelled permits may or may not be associated with a completed well, abandoned status generally refers to a previously existing well.

8.7.3.6 Domestic use permits (Figure 8-4)

Domestic water withdrawals include non-community public water systems and rural domestic users. **Tables 8-6** through **8-8** show that ground-water permits for domestic use (DOM) outnumber permits for all other uses combined, with 418 SEO

Table 8-10. SEO municipal well permits listed with a status other than Fully Adjudicated in the Bear River Basin.

Municipality or Community	Well Name	WSEO Permit Number	Permit Yield (gpm)	Well Depth (feet)	Permit Status	New since
Evanston	EVANSTON WELL #3	P120.0G	650	21	Incomplete	Yes
WWDC / USDI - BLM	DEER MOUNTAIN # 6	P146167.0W	100	47	Complete	Yes Yes
Evanston	EVANSTON WELL #1	P425.0C	600	30	Incomplete	Yes
Evanston	EVANSTON WELL #2	P426.0C	500	10	Incomplete	Yes
Evanston	EVANSTON WELL #5	P588.0W	600	90		Yes
Evanston	EVANSTON WELL #8	P589.0W	500	10		Yes
Evanston	EVANSTON WELL #7	P7141.0W	600	0		Yes
Totals			3,550			

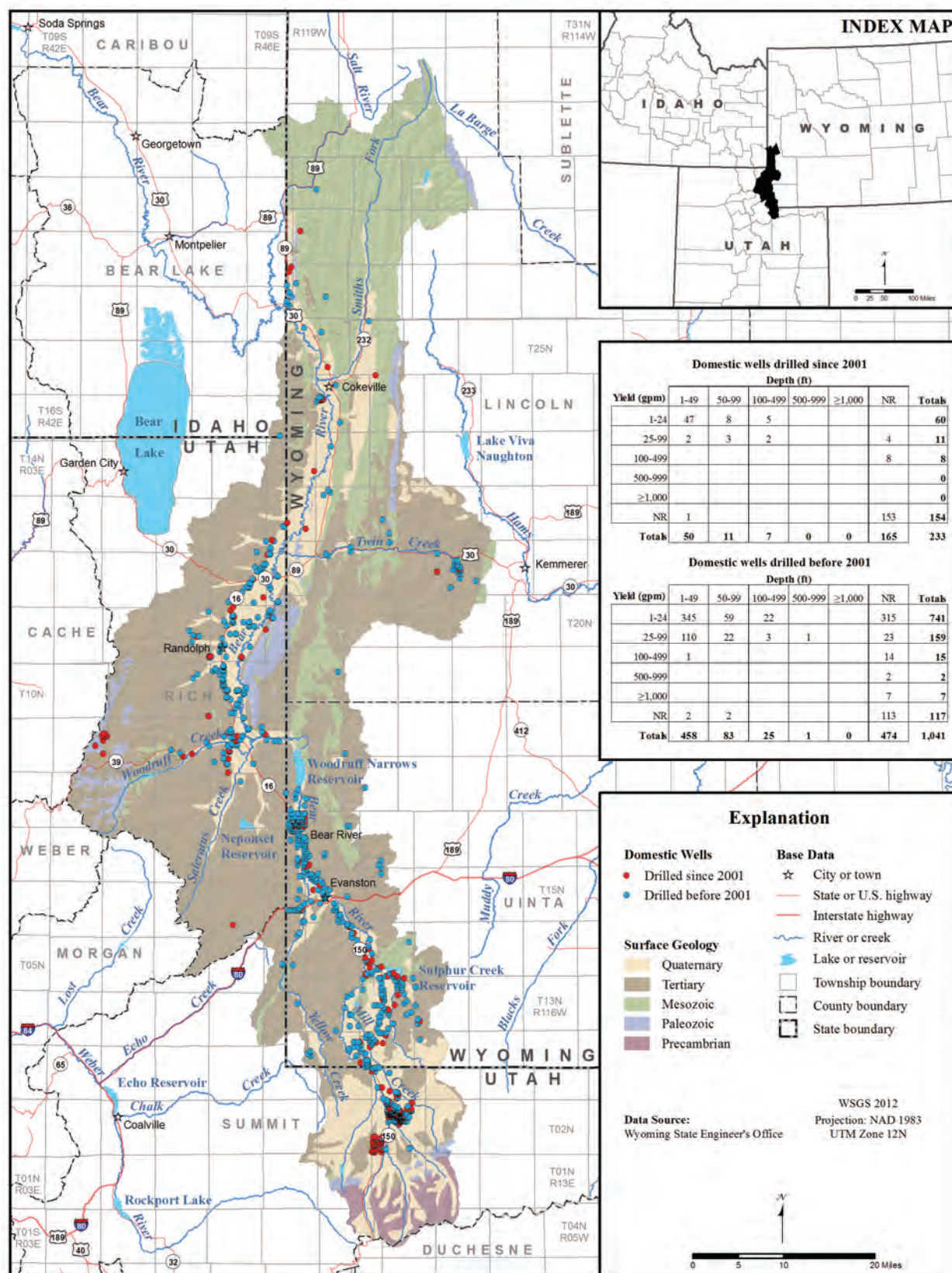


Figure 8-4. Wyoming SEO, Utah DWR, and Idaho DWR permitted and drilled domestic wells, Bear River Basin.

permits, 416 UDWR permits, and one IDWR permit.

Figure 8-4 shows the distribution of likely drilled domestic-use permits in the entire Bear River Basin issued before and after January 2001. Most domestic wells are located in rural areas, generally outlying population centers along rivers and other surface drainages. Most wells are completed in Quaternary and Tertiary geologic units; however, domestic-use wells have also been permitted over a wide range of depths within virtually all hydrogeologic units (including confining units) throughout the Bear River Basin, pointing to the fact that useful quantities of relatively shallow groundwater can be found at many locations and that the distribution of recharge is widespread. The depth vs. yield tables on **Figure 8-4** show that basin-wide, the largest percentage of permits issued before and since January 2001 allow well depths up to 999 feet and yields up to 99 gpm. Many domestic use permits do not provide any recorded depth information.

8.7.3.7 Source Water Assessment Program (SWAP) wells and springs

The SWAP, a component of the federal Safe Drinking Water Act, is designed to help states protect public water systems (PWS) and applies to both municipal and non-community public systems. The voluntary program, administered by the WDEQ Water Quality Division (WQD), encourages the development of source-water assessments and Wellhead Protection Plans (WHP) for groundwater PWS. A source-water assessment entails determining the source-water contributing area, inventorying potential sources of contamination to the PWS, determining the susceptibility of the PWS to identified potential contaminants, and summarizing the information in a report. An important aspect of these reports relative to this study is that the producing hydrogeologic unit is commonly identified. As discussed in **Section 5.7.4**, the individual PWS reports provide valuable information on recharge areas, resource vulnerability and local sources of potential contaminants

for specific groundwater sources. The development and implementation of SWAP/WHP assessments and plans is ongoing throughout Wyoming. Additional information on the SWAP in Wyoming can be accessed at:

<http://deq.state.wy.us/wqd/www/SWP%20WHP/SWAP%20FAQs.asp>.

Table 8-11 provides SEO water right permit number, yield, producing unit and depth data for 17 SWAP wells in the Bear River Basin. The SEO permit numbers shown can be correlated with the wells shown in **Tables 8-9** and **8-10**. Although most wells in the SWAP database produce groundwater from alluvial deposits and Tertiary aquifers, the Cretaceous Thomas Fork Formation is also identified as a producing unit in **Table 8-11**.

Figure 5-11 shows the geospatial distribution of SWAP wells in the Bear River Basin and their relative susceptibility to potential contaminants. Insert maps on **Figure 5-11** are scaled to show more detail in areas where the wells are closely spaced.

8.7.3.8 Industrial use and CBNG permits

Table 8-6 lists 11 SEO permits for industrial (IND) use; no industrial use permits are listed for Utah or Idaho in the Bear River Basin. Primary industrial uses in the Bear River Basin have included natural gas processing, tertiary oil recovery, phosphate mining operations, sawmill operations, aggregate and gravel mining. The SEO database does not identify specific industrial uses; individual permit summaries must be reviewed for that information. Permit status for the Bear River industrial permits found in the SEO database are listed as “Incomplete” or “Not Available” so it is not possible to determine if the industrial wells are currently in use. The 2011 Bear River Water Plan (WWDO 2012) identified two current industrial uses and noted that industrial withdrawals and consumptive uses had decreased markedly since 2001 because the permitted users switched to water saving processes.

Table 8-11. WDEQ Source Water Assessment Program (SWAP) wells and springs used for municipal and non-community public water supply in the Bear River Basin.

Well Name	Public Water System ID	WSEO Permit No.	Yield (gpm)	Well Depth (ft)	Source Type	Producing Unit
Deer Mountain Ranch Subdivision	5601019-104	P146167	100	544	Well	Wasatch Fm
Deer Mountain Ranch Subdivision	5601019-101	P65876W	26	350	Well	Wasatch Fm
Deer Mountain Ranch Subdivision	5601019-103	P84238W	25	760	Well	Wasatch Fm
Deer Mountain Ranch Subdivision	5601019-102	P84240W	25	390	Well	Wasatch Fm
Town of Cokeville	5600015-102	P110471W	450	173	Well	Thomas Fork Fm
Town of Cokeville	5600015-103	P110472W	700	175	Well	Thomas Fork Fm
Evanston Lodge NO. 2588-BPOE	5601147-101	P57307W	25	370	Well	Not listed
Evanston Port-of-Entry	5601217-101	P82908W	25	218	Well	Not listed
BP America Production - Painter Reservoir	5601012-101	P72025W	25	700	Well	Wasatch Fm
BP America Production - Painter Reservoir	5601012-102	P76129W	25	701	Well	Wasatch Fm
BP America Production - Anschutz Ranch	5600790-101	P72408W	10	1510	Well	Wasatch Fm
BP America Production - Anschutz Ranch	5600790-102	P72409W	10	1680	Well	Wasatch Fm
Meadow Vista Mobile Home Park	5600897-101	P53482W	65	260	Well	Wasatch Fm
Wyoming Downs Horse Racing	5601113-102	P73997W	100	260	Well	Knight Fm (database)
Wyoming Downs Horse Racing	5601113-101	P73998W	100	240	Well	Knight Fm (database)
Yellow Creek Estates MHP	5600820-101	P51014W	125	260	Well	Wasatch Fm
Yellow Creek Estates MHP	5600820-102	P56362W	175	120	Well	Wasatch Fm

8.7.3.8.1 Groundwater use for oil and gas production

Groundwater associated with oil and gas production includes “produced water” withdrawn as a byproduct of oil and gas extraction from hydrocarbon reservoirs, and water utilized in the production and refining of petroleum resources. In some cases, produced water is used in production and refining operations; in others, water for operations is ob-

tained from surface or underground sources. Some water plans (e.g., the 2012 Wind/Bighorn River Basin Water Plan) have treated produced water withdrawals as industrial groundwater use, while others (e.g., the 2006 Platte River Basin Water Plan) have included only water used for production and refining operations in estimates of industrial use. This study presents estimates both for groundwater volumes used for production and refining, and for produced water (**Table 8-1b**). Information

on groundwater withdrawn for production and refining was derived from the 2011 Bear River Basin Water Plan (WWDO 2012). Information on produced water associated with conventional oil and gas operations was obtained from the WOGCC website: <http://wogcc.state.wy.us/>.

Figure 5-4 shows the locations of conventional oil and gas fields in the Bear River Basin, where groundwater is produced as a byproduct. Conventional oil and gas operations in the Bear River Basin co-produced an average of 466 ac-ft of water per year from 2003 through 2012 (**Table 8-1b**; WOGCC, 2013). There are several options for managing water co-produced with conventional oil and gas operations. The viability of these strategies, however, depends on the quality and the volume of the water produced:

- Underground injection for storage, permanent disposal, or enhanced recovery (water flooding, pressure maintenance)
- Infiltration from unlined pits and subsurface structures (tin horns and other Class V injection facilities – generally no longer allowed)
- Evaporation from pits, landspreading, and landfarming
- Surface discharge for surface flows and associated uses:
 - domestic use (rare)
 - wildlife and livestock watering
 - wetlands, fish, and other aquatic wildlife habitat maintenance
 - irrigation
- General industrial uses:
 - drilling
 - road application and dust control
 - fire control
 - washing
 - power generation

Figures 5-4 and **5-5** show the locations of Class II and Class I injection wells, respectively, that can inject produced water from oil and gas operations. The WOGCC, BLM, and EPA permit Class II wells to operators for disposal of their own produced water. The WDEQ permits Class I wells for disposal of non-hazardous wastewaters from a

variety of sources. The WOGCC and BLM also permit evaporation pits for disposal of produced water, generally in the gas or oil field of origin.

Figure 5-6 shows the location of commercial disposal pits where produced water and other waters deemed non-hazardous are evaporated.

Produced water of suitable quality can be put to beneficial use (e.g., stock watering, agriculture, drilling and industrial dust suppression). Otherwise, produced water is primarily discharged to the surface under the regulation of WDEQ NPDES/WYPDES permits or re-injected for enhanced recovery of oil and gas from depleted reservoirs or strictly as a means of disposal. An average of 222 ac-ft/yr of water was injected from 2003 through 2012 (**Table 8-1b**; WOGCC, 2013), but it is unknown if this is produced water or groundwater withdrawn solely for enhanced recovery. Estimates of the volume of produced water discharged in the Bear River Basin under the WYPDES program are not readily available.

Produced water volumes that are discharged to the surface or put to other uses are generally considered to be partially-consumptive and, in a few cases, wholly consumptive. Almost every produced water management strategy involves some consumptive losses to evapotranspiration. On the other hand, injecting produced water into hydrogeologic units at depths where there is minimal chance of future withdrawal effectively removes it from the water budget of the basin and is wholly consumptive. In fact, most produced water probably would not have been withdrawn for any other use. Produced water discharged to the surface under a WYPDES permit generally adds to streamflows and increases the growth of vegetation. The water balance developed within this study did not consider produced water on either side of the equation.

Produced water withdrawals in the Bear River Basin are associated with conventional oil and gas operations, with lesser amounts used for coal mining. In conventional oil and gas production, groundwater is produced as a byproduct that is primarily disposed of using various methods; a smaller amount is used beneficially during production,

refining, or associated operational activities (e.g., drilling, dust suppression).

8.7.3.8.2 Groundwater use for coal mining

Coal mining operations require ground and surface water withdrawals for several mining processes. The most important include mine de-watering, mineral extraction, milling and processing operations, mine reclamation, dust suppression and personnel uses. In many cases, mining operations will reuse produced water of sufficient quality for other operations (e.g., dust suppression). Otherwise, surplus water is commonly discharged, under regulatory permit, to pits and/or surface drainage where a part is consumptively lost to evapotranspiration and the remainder returns to shallow aquifers through infiltration.

Currently the only active coal mining permit in the Bear River Basin is held by Westmoreland Kemmerer, Inc., for the Kemmerer Coal Mine, located west of Kemmerer.

8.7.3.8.3 Groundwater use for non-energy minerals development

Groundwater withdrawals for non-energy minerals development in the Bear River Basin are primarily associated with sand, gravel, and clay production. **Figure 5-8** shows the locations of groundwater permits for these uses in the Bear River Basin. Mining permits can be viewed on WDEQ Land Quality Division website: http://deq.state.wy.us/lqd_permit_public/.

8.7.3.9 Monitoring wells (Figure 8-5)

Table 8-6 lists 147 SEO groundwater permits for monitoring wells in the Bear River Basin. Monitoring wells are typically used to monitor the levels and the quality of groundwater associated with a contaminated site or a potentially contaminated site (e.g., an underground fuel storage tank) or to monitor for groundwater impacts from various activities (e.g., mining, waste management). When used for monitoring alone, these wells have no permitted yield; however, there may be a permitted

yield for other, secondary uses. The SEO required permits for monitoring wells of four inches or less in diameter only through 2004; therefore, the data for these permits is incomplete.

Figure 8-6 shows the distribution of likely drilled SEO monitoring well permits in the Bear River Basin and permits issued before and after January 2001. Most monitoring wells are located near Evanston or the Kemmerer coal mine. The depth vs. yield tables on **Figure 8-6** show that while permits have been issued for all depth categories, by far the largest number were issued for depths of 0 to 50 feet reflecting monitoring of the shallow water table aquifers that are most susceptible to contamination. Although, recorded depths are available for most monitoring wells in the database, only one well permit includes recorded yield data. Many of the monitoring wells were permitted after 2001; however, as discussed above, even this number is probably understated, per the 2004 SEO policy change.

8.7.3.10 Permits for other and miscellaneous uses (Figure 8-6)

Table 8-6 indicates that 112 permits have been issued for “other” uses and 408 permits for “multi-use” wells have been granted by the SEO (**Table 8-6**). Multi-use permits list more than one use; for example a permit that shows both “domestic and “stock” uses is a multi-use permit. **Table 8-7** lists 134 and 229 UDWR permits issued for “other” and “multi-use” wells in the Utah portion of the basin. Some of the “multi-use” permits issued test wells are generally employed for aquifer testing to determine aquifer characteristics. Information on specific miscellaneous use and test wells may be found in some permit applications available online. However, developing detailed information for specific miscellaneous use and test wells was beyond the scope of this study.

Figure 8-6 shows the distribution of likely drilled wells permitted for “miscellaneous use” and “other” wells in the Bear River Basin, and permits issued before and after January 2001. “Miscellaneous use” and “other” wells are located throughout the Bear River Basin and are generally concentrated in mineral development areas and along rivers and

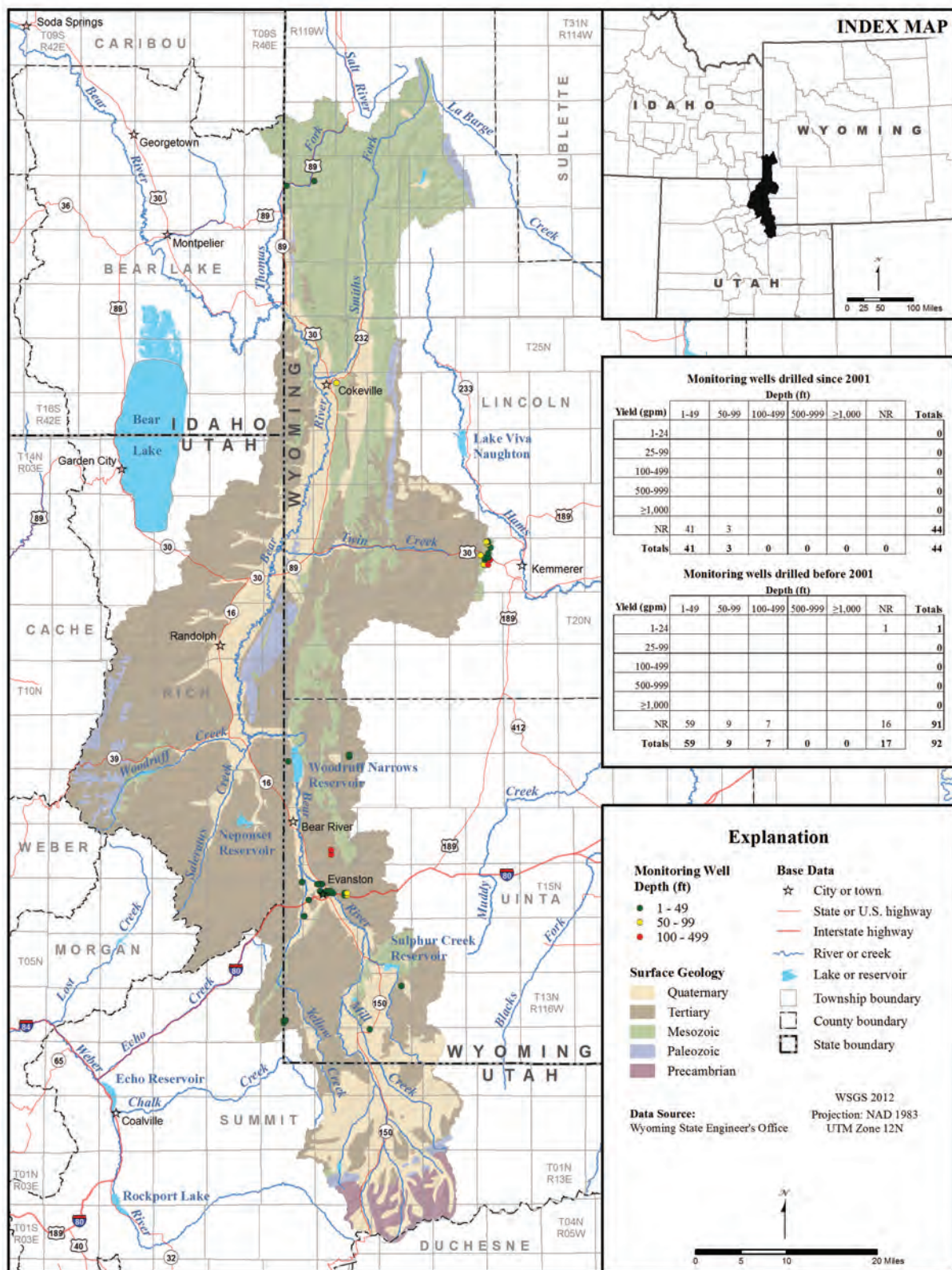


Figure 8-5. Figure 8-5. Wyoming SEO, Utah DWR, and Idaho DWR permitted and drilled monitoring wells, Bear River Basin.

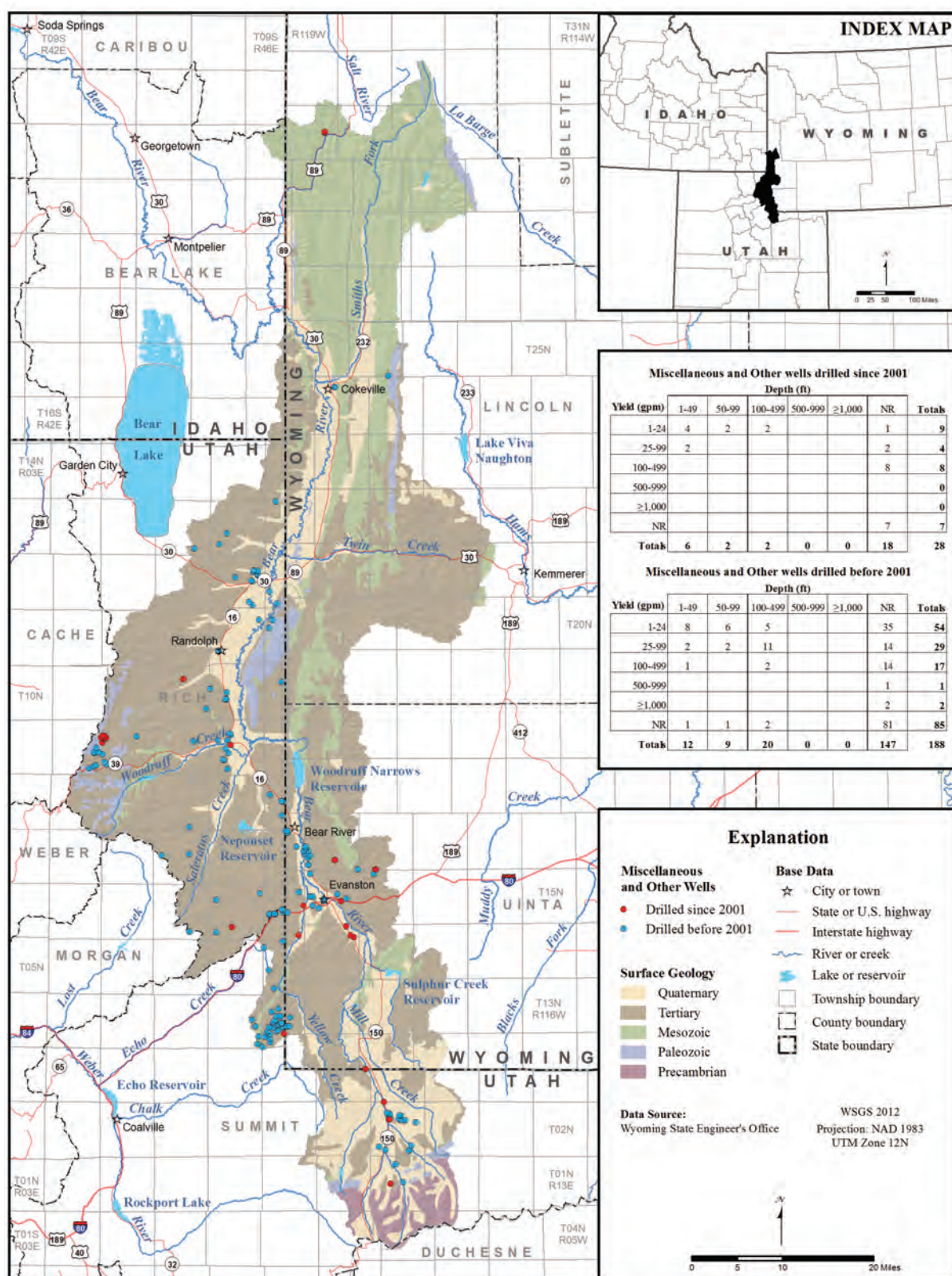


Figure 8-6. Wyoming SEO, Utah DWR, and Idaho DWR permitted and drilled miscellaneous and other wells, Bear River Basin.

larger surface drainages. The depth vs. yield tables on **Figure 8-6** show that most groundwater permits have been issued for depths up to 500 feet and for yields of 0 to 99 gpm for both total permits and permits issued since 2001. Most of these permits have no recorded depth.

8.7.3.1 | Hydrothermal use

The Bear River Basin has no potential for high-grade geothermal energy development.

8.8 Groundwater interference/interconnection with surface water

The potential for interference between wells and well fields located within areas of interconnected surface and groundwater that exhibit historically high levels of drawdown must be considered when assessing the historic, current, and future use of groundwater in the Bear River Basin. Generally, these issues are addressed within the state's institutional and regulatory framework for groundwater development (**Chapter 1**), primarily by the Amended Bear River Compact of 1978.

8.8.1 Interference between wells

As a well withdraws water from an unconfined aquifer, it depresses the groundwater level around the well casing in a generally radial configuration, called a "cone of depression". In areas where several actively pumping wells are sited in close proximity to each other, their respective cones of depression may overlap and "well interference" may result. If well interference becomes excessive, aquifer water levels may drop below the depth of some wells causing conflicts between users. In Wyoming, the SEO may address cases of excessive well interference by recommending the formation of a groundwater control area wherein groundwater uses are actively managed by a groundwater control area advisory board. According to Wyoming State Statute WSS 41-3-912, a "control area" can be designated by the Board of Control on the recommendation of the State Engineer for any of the following reasons:

- The use of underground water is approaching a use equal to the current recharge rate.

- Groundwater levels are declining or have declined extensively.
- Conflicts between users are occurring or are foreseeable.
- The waste of water is occurring or may occur.
- Other conditions exist or may arise that require regulation for the protection of the public interest.

Currently, there are no control areas designated in the Bear River Basin. Additional information about groundwater control areas can be found online at: <https://sites.google.com/a/wyo.gov/seo/groundwater/groundwater-control-areas-advisory-boards>

8.8.2 Interconnection between groundwater and surface water

Surface flows are subject to strict water rights, and conflicts occur where groundwater extraction affects surface flow. Although the Wyoming Constitution establishes that all surface water and groundwater within Wyoming's borders is owned by the state, the right to put surface water and groundwater to beneficial use is permitted via water rights issued by the Wyoming SEO and adjudicated by the Wyoming Board of Control. Surface water resources are subject to interstate agreements that limit how much streamflow can be depleted before leaving the state. Furthermore, conflicts among users within the state or across state lines can occur where groundwater extraction may affect surface flows. Although interconnection between groundwater and surface water is not currently a significant water rights issue in the Bear River Basin, it could become a point of contention in the future as the basin's population grows.

To avert present and future conflicts over the allocation and use of water flows within the Bear River Basin, the states of Idaho, Utah and Wyoming agreed to the Amended Bear River Compact in 1978. The compact divides water administration in the Bear River among three geographically defined divisions. The Upper Division encompasses the reach of the Bear River that extends from its headwaters in the Uinta Mountains to the Pixley diversion dam in sec. 25, T. 23 N., Range 120 W. of the

Sixth Principal Meridian in Wyoming. During a compact defined water emergency in the Upper Division, percentage allocations are made to the Utah and Wyoming Sections and distribution of divertible flow is managed by diversion by the two states. The Central Division extends from below Pixley Dam to the Stewart diversion dam in sec. 34, T. 13 S., R. 44 E., Boise Base Meridian in Idaho; during a water emergency, divertible flow is allocated by percentage to Wyoming and Idaho. In the Lower Division, which extends from the Stewart Dam to the Great Salt Lake, divertible flows are allocated by a commission approved delivery schedule.

The portion of the Bear River drainage basin, examined in this report, consists of the entire Upper Division and those parts of the Central Division that are tributary to the Bear River upstream of the Idaho-Wyoming border (**Figure 3-1**). **Appendix D** (SEO, 2006) contains a copy of the Amended Bear River Compact (1978). The compact is administered by the Bear River Commission (<http://www.bearrivercommission.org/>) composed of three commissioners from each signatory state. The Interstate Streams Division of the SEO, in conjunction with the Water District IV staff, administers the provisions of the compact that fall under the authority of the state of Wyoming.

Along with the distribution of water specified for each of the divisions, Article VI of the compact allocates an additional 13,000 ac-ft annual total of surface and connected groundwater each to Wyoming and that portion of Utah above Stewart Dam for beneficial uses applied on or after January 1, 1976. Historically, Wyoming has used only a small portion of this additional allocation, so it is likely that future groundwater development in the Bear River Basin allow Wyoming to develop and utilize its 13,000 ac-ft allocation. In Wyoming, the SEO monitors surface water and connected groundwater depletions owing to the additional allocation.